material covering outer surface **33** of cylinder **27** and into which actuators **49** press a pattern of Braille text characters as it moves past, and which is capable of such character retention through reading area (or aperture) **39**. After passing reading area **39**, rollers or similar such devices are provided to flatten (and thus reshape so that no impressions remain) the surface of the plastic material, thereby providing a blank, unwritten, surface **33** for new text to be written. The plastic material must be sufficiently stiff to permit reading without undue deformation of the material, but sufficiently pliable to permit writing, flattening, and rewriting.

[0066] In still another embodiment, shown in **FIG. 3**, the Braille dots are externally set in a mechanically plastic material as described above with respect to **FIG. 2**, but instead of being set on surface **33** of wheel **27**, they are set on surface **55** of belt **57** moving around two wheels **59** and **61**. Instead of one or two characters being exposed at any given time at reading aperture **39**, several characters, up to an entire line of Braille text, are exposed. Back plate **63** keeps belt **57** from flexing while the user reads the Braille at reading aperture **39**. This method sacrifices some simplicity for the ability to display an entire line at a time.

[0067] The user may choose to operate such a display in any of several different modes. The display can be configured to update continuously and with wheels **59**/**61** rotating continuously. The user places a finger where the text first appears, and stops the motion of the display in order to re-read characters that have just moved past the finger. Alternatively (depending upon reading aperture size), the display can be configured to update an entire line at a time, and is then stopped while the user reads the entire line. When deploying the display apparatus of this invention in this mode, belt **39** can be made wider, and more actuators **49** can be added, so more than one line can be displayed at a time if desired. With a sufficiently long line of actuators and a sufficiently wide belt, an entire page of Braille text can be updated and displayed at once.

[0068] Moreover, where a multiple-line extended Braille text display is desired, separate belts **57** (and drive wheels **59**/**61**) may be provided for each line of text. This would allow for utilization of much slower actuators **49**. While the user is reading one line, other lines are slowly being updated. Satisfactory throughput can be provided even if the individual actuator groups in assembly **45** (triads, for example, for six-dot Braille) produce Braille text at a fraction of the user's reading speed.

[0069] **FIG. 4** shows an example of one method of implementation of refreshable Braille reader **65** in accord with the various embodiments of this invention. This implementation includes interface and control logic **69**, power electronics **71** to drive the transducers (actuators) and rotation of Braille wheel **27**, and physical user interface **73**. The physical user interface includes Braille wheel **27** and additional controls **75** such as stop, start, forward and reverse buttons and a speed control for adjustment of the speed of rotation of Braille wheel **27** to provide a desired reading rate.

[0070] In addition to signals from user controls **75**, feedback path **77** may include signals from sensors (discussed herein below) that observe the performance of Braille wheel **27**, in order to detect any errors and/or to tune performance. A standard port interface **79** (which may be a parallel port, serial port, USB, or infrared link, for example) connects reader **65** to text driver device **81** such as an electronic book reader, a PDA, or a notebook or desktop computer. Text driver device **81** is programmed to provide the signals needed by Braille reader **65** over port connection **79** to control logic **69**.

[0071] It is the responsibility of the control system to produce the appropriate Braille text and to respond to user input. The commands the user may wish to send to reader **65** at controls **75** include those which are typical of an electronic book reader (move forward, move back, bookmark, dictionary and the like), and commands which are specific to the motion-based Braille reader of this invention. The latter class of commands may include start/stop, speed adjustment and repeat (play back of words to clarify an uncertainty or search for data). A display protocol may be implemented to aid identification of changes in context, as when the user jumps to a different location in text or looks up a reference. One example of such a protocol includes a separator (a brief blank interval, for example) whereby cylinder **27** rotates but nothing is displayed.

[0072] Adjustment of the speed of rotation of Braille wheel **27** (and thus the rate at which text is displayed) must be provided for adaptation to different users, and also for adjustment by a particular user for different applications (reading for entertainment, reading for study, and the like). A typical expert reading rate for Braille may be considered as 125 words per minute, which translates to roughly 32 Braille characters per second generated, and 20 cm/s motion of wheel surface **33** at display aperture **39**. A very fast reading rate would be considered 250 words per minute. Ability to produce text at the desired reading rate range defines the performance requirements for transducers **49** to be used to produce the Braille characters.

[0073] Turning now to **FIGS. 5 and 6**, a passive pin displacement system for use with either an internal or an external (**FIG. 2**) actuator reader design is illustrated. Unlike other methods in which Braille dots are mechanically deformed in order to store their binary status (raised dot or no dot) after writing, this system employs, as the selected surface characteristic **31** of wheel **27**, pins that are mechanically simple and passively manipulated or retained in position by the physical structures they encounter during the course of rotation of wheel **27**. Active control is used only at the point where the actuators set the text on wheel **27** by manipulation of the pins.

[0074] Referring to **FIG. 5, a** collection of actuators (typically three for six-dot Braille or four for eight-dot Braille) set the positions of the pins described hereinafter (raised or lowered relative to reading/display surface **33**) one column at a time, for each of the three or four endless rows of dots (one actuator acting in each row). A Braille cell contains two columns of three or four dots, so two write operations are required to write each Braille cell.

[0075] After the Braille dots are written, they immediately move into contact with a physical structure that they slide along as the wheel rotates, the structure holding the pins in whatever position they are set by the actuators (either raised or lowered). This structure underlies the entire reading area **39** of the display aperture, where the user may place one or more fingers to feel the Braille dots formed by relative position of pin ends and surface **33**. The structure holds the Braille dots firmly in their relative position on wheel **27**,